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Engineering and Design
ROCK MASS CLASSIFICATION DATA REQUIREMENTS
FOR RIPPABILITY

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ROCK MASS CLASSIFICATION DATA REQUIREMENTS FOR RIPPABILITY

1. Purpose. This ETL contains information on data required for rock mass classification with respect to rippability.

2. Applicability. This ETL is applicable to all field operating activities having civil works design responsibilities.

3. References and Bibliography.

a. References.

(1) EM 1110-1-1802, Geophysical Exploration.

(2) Bieniawski, Z. T., Tunnel Design by Rock Mass Classifications, Technical Report GL 79-19, 1979. Available from U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180.

b. Bibliography.

(1) Weaver, J. M., "Geological Factors Significant in the Assessment of Rippability," The Civil Engineer in South Africa, Vol. 17, No. 12, December 1975.

(2) Caterpillar Tractor Company, "Handbook of Ripping," 6th Edition, Caterpillar Tractor Company, Peoria, Illinois, June 1978.

(3) Caterpillar Tractor Company, Caterpillar Performance Handbook, Edition 13, Section 1-10, Caterpillar Tractor Company, Peoria, Illinois, October 1982.

(4) Church, H. K., "Two Exceptions to Seismic Principles," World Construction, Vol. 27, No. 5, pp 26-32, 1974.

4. Background. The ripper is a relatively narrow-profile implement (as compared to a plow) which penetrates the earth and is pulled to loosen soil or rock material for excavation. In the early days of our technological development, tractor-drawn rippers were used to increase the usefulness of scrapers. The advent of the tractor-mounted ripper several decades ago offered increased possibilities for work in rock because of the increased force on the ripper tooth. Since that time, increases in tractor weight and horsepower, as well as improvements in

ripper design, have further extended the capability of the ripper in rock. Much rock, which was traditionally loosened for excavation by drill and blast methods, is now rippable.

5. Rock mass parameters influencing rippability. Because relatively harder and tighter rock is now rippable, a casual field observation rippability assessment has become more difficult. A careful assessment based on an evaluation of several rock mass parameters is often needed. Such an evaluation frequently requires field data from core borings and/or geophysical work (bibliography 3b(1)). Six geological factors which are likely to influence the assessment of rippability are as follows:

a. Rock type. Sedimentary rocks are usually the most easily ripped due in part to their bedding characteristics. Common metamorphic rocks such as gneiss, quartzite, schist, and slate are generally more difficult but vary in rippability with their degree of lamination or cleavage. Igneous rocks such as the granitic and basaltic types are the most difficult to rip because they lack the stratification and cleavage planes needed to rip hard rock.

b. Rock structure. Discontinuities in the form of faults, fractures, joints, cleavages, schistocity, bedding, and laminations all act as planes of weakness facilitating ripping. The continuity, spacing, and strike and dip orientation of joints and fractures and the presence of gouge material are of particular importance in assessing rippability.

c. Rock hardness. Softer rocks having lower unconfined compressive strengths are more easily ripped.

d. Rock weathering. The greater the degree of weathering the more easily the rock is ripped.

e. Rock fabric. Coarse grained rocks rip more easily than fine grained rocks.

f. Seismic wave velocity. The velocity of a shock wave depends on the density and degree of cementation of materials. Rock masses having lower wave velocities are more easily ripped.

6. Rippability Assessment: Seismic Wave Method. The seismic wave velocity method for rippability assessment was developed first during 1958 by the Caterpillar Tractor Company (bibliography 3b(2)). The physical principal used for the determination of rippability is that seismic waves travel faster through rock having a higher bulk density than through rock less consolidated. The wave velocity (average) is influenced by such geological factors as rock hardness, stratification, degree of fracturing, and amount of decomposition or weathering, all of which influcence rippability. In general, a lower seismic wave velocity

indicates material more easily rippable. However, the average velocity of a seismic wave alone, does not correlate well with rippability. For example, a weathered or badly fractured granite having a smiliar wave velocity as a rippable siltstone may not be rippable. Caterpillar found that a comparison of the wave velocities recorded with those obtained in a similar material from previous experience gives a good indication of ripper performance. They have published charts showing ripper performance as related to seismic wave velocities for their equipment (bibliography 3b(1) and (2)). A typical example of a ripper performance chart is shown in Figure 1 (See Inclosure 1).

7. Use of Refraction Seismograph. The refraction seismograph can be used to determine both the mass density and the thickness of the upper layers. Its cost is low compared to closely spaced borings. This method generally gives reliable results. However, several exceptions do exist. In the case where a layer is underlain by one of lower velocity, (hidden layer problem), interpretation is difficult and inaccuracy can be expected (reference 3a(1) page 3-9). In areas where bedrock is covered with large boulders or where the bedrock surface is highly uneven due to solutioning or structural anomalies, seismic velocity data may be too unreliable for evaluating rippability. Church (bibliography 3b(4)) suggested a method to compensate for this condition where it is suspected which involves the lowering of velocity ranges for rippability in the hard ripping classifications.

8. Rippability Assessment: Rock Mass Rating Method (RMR). It is possible to obtain an indication of rippability using Bieniaski's geomechanics classification system (reference 3a(1)). Bieniawski proposed the geomechanics classification system (RMR) to rate a rock mass by assigning weighted numerical values to each of six rock mass parameters. The final rating was the sum of the weighted parameters. An inverse relationship exists between the classification description and rippability, that is, a material classified as "very poor rock" for tunneling would be considered easily rippable. Weaver (bibliography 3b(1)) proposed a rippability rating chart based upon a modification of the geomechanics rating system; a similar chart is shown in Figure 2. The user would determine a total rippability rating by adding the rating for each of the rock mass parameters shown, resulting in a quantitative determination of relative ripping difficulty. The lower ratings correspond to easier ripping and the higher ratings correspond to more difficult ripping or required blasting. Weaver's system uses seismic wave velocity as a very significant parameter and does not consider groundwater inflow as used in the geomechanics rating system.

9. Correlation with Tractor Size. Rippability for a given tractor selection is correlated with the total rippability rating in Figure 3. This figure shows the corresponding seismic velocities for average

conditions; the given velocity scale may be used where adverse conditions such as unfavorable orientation of bedding planes or joints do not exist (bibliography 3b(2)).

10. Summary. When data can be obtained on the parameters required for use of the rock mass rating or other similar systems in rippability assessment, their use will supplement an assessment using only seismic data and rock type and should enhance overall engineering judgment. In particular, the use of the rock mass rating system gives the user a means of quantifying rippability assessments while taking into account a wide spectrum of rock mass parameters. Although seismic wave velocity is a good indicator of rippability, its use must be tempered by judgment. For example, the predicted production from Caterpillar's production estimating charts (bibliography 3b(3)) is lowered where adverse conditions exist such as thick bedding, vertical lamination, or any other factor which would adversely affect production. Validation of the recommended procedures in this ETL can only be made after the procedures have been applied on construction contracts in differing geologic materials. However, these procedures are not always applicable to rock excavation. Even in marginally excavatable material, the maximum seismic velocity applicable to the procedure is about 10,000 fps. Most crystalline, unweathered and unfractured rock will exceed this velocity.

FOR THE COMMANDER:

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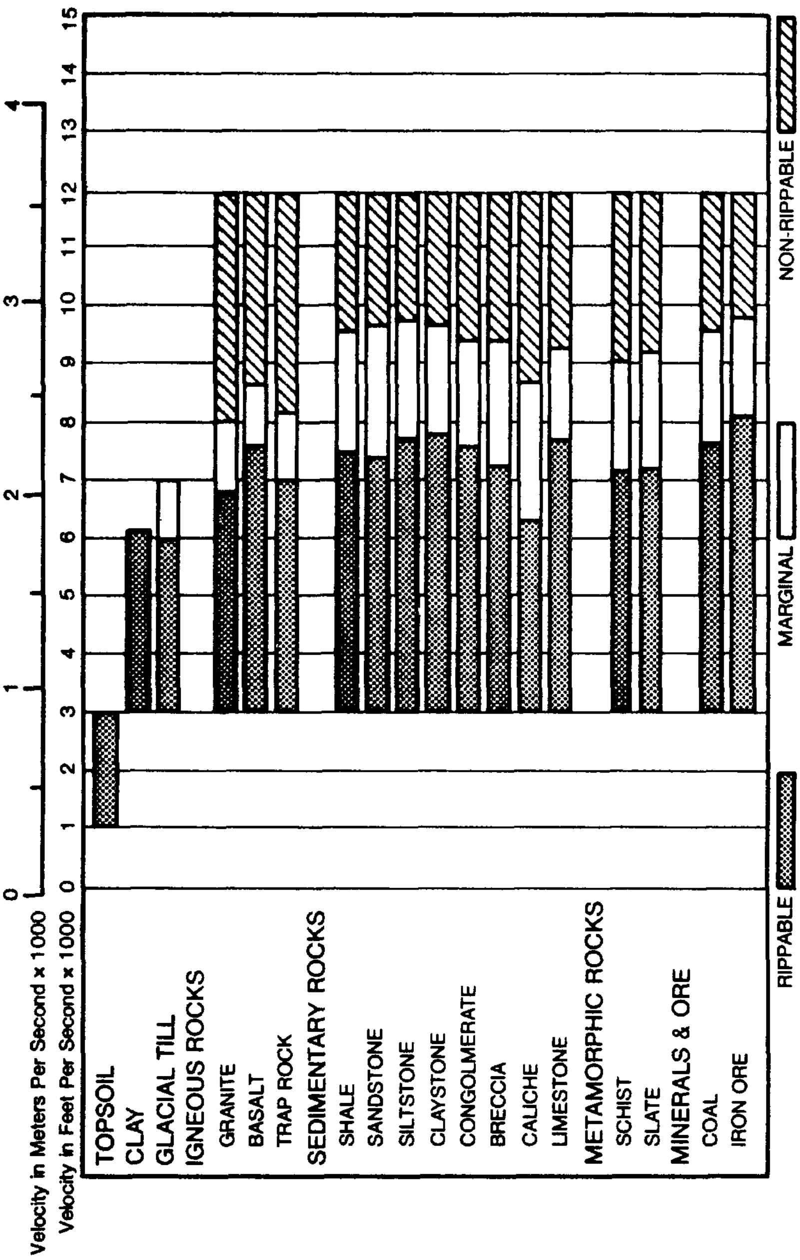

Figure 1.
D8L Ripper Performance Related to Estimated Seismic Wave Velocity.
Multi or Single Shank No. 8 Ripper from Caterpillar Performance Handbook, 1982.

Inclosure 1

	Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock
1.	Seismic velocity (ft/s)	7000	7000-6000	6000-5000	5000-4000	4000-1500
	Rating	26	24	20	12	5
2.	Rock hardness*	Extremely hard 10000 psi	Very hard 10000-2900 psi	Hard 2900-1450 psi	Soft 1450-435 psi	Very soft 435 psi
	Rating	10	5	2	1	0
3.	Rock weathering	Unweathered	Slightly weathered	Weathered	Highly weathered	Completely weathered
	Rating	9	7	5	3	1
4.	Joint spacing (mm)	3000	3000-1000	1000-300	300-50	50
	Rating	30	25	20	10	5
5.	Joint continuity	Noncontinuous	Slightly continuous	Continuous - no gouge	Continuous - some gouge	Continuous - with gouge
	Rating	5	5	3	0	0
6.	Joint gouge	No separation	Slight separation	Separation 1 mm	Gouge 5 mm	Gouge 5 mm
	Rating	5	5	4	3	1
7.	Strike and dip orientation	Very unfavorable	Unfavorable	Slightly unfavorable	Favorable	Very favorable
	Rating	15	13	10	5	3

* Corresponding to unconfined compressive strength.

Figure 2. Rippability Rating Chart (Weaver 1975)

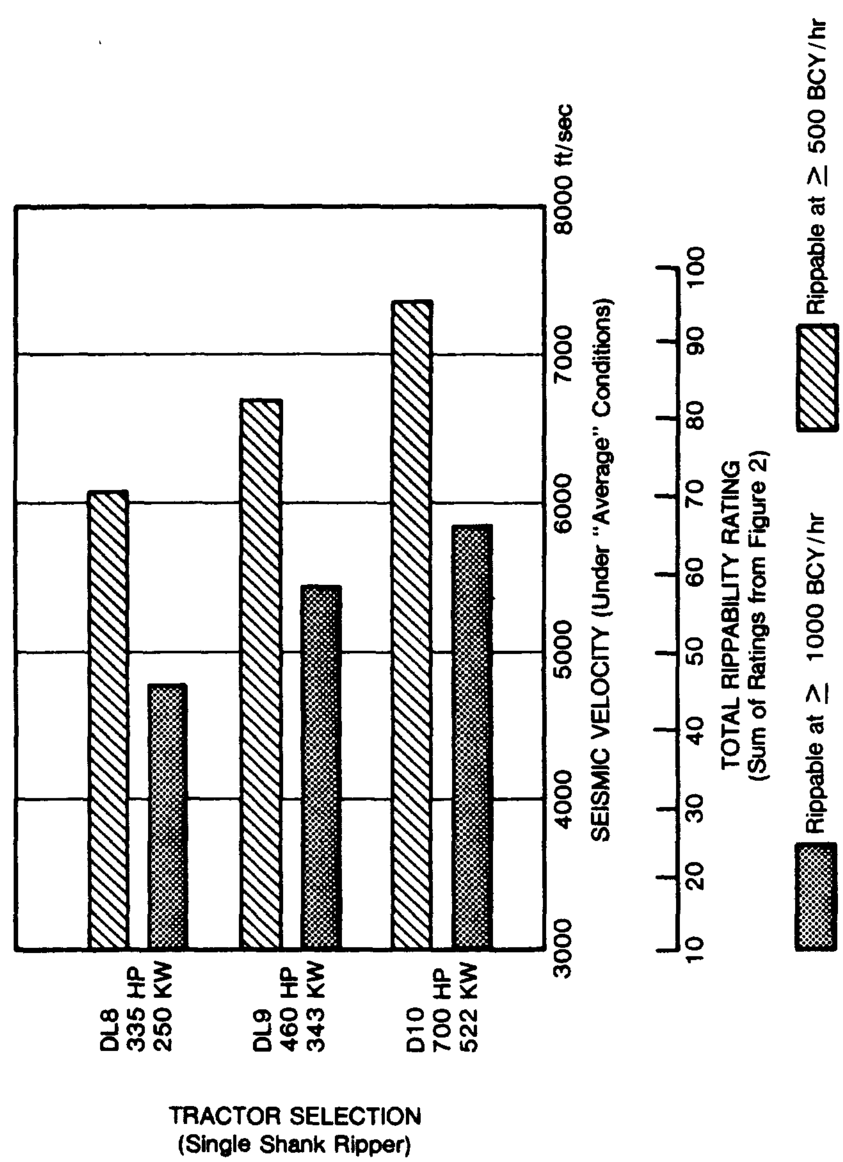

Figure 3.
Tractor Selection Based on Rippability Rating from Caterpillar Performance Handbook, 1982.